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RESEARCH MEMORANDUM

V. 8, No. 22

for

U. S. Army Ordnance

FLIGHT TESTS OF FIFTEEN T-231 GUN-LAUNCHED ROCKET PROJECTILES

By Wade E. Lanford

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON
26 JUN 1956

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NACA RM SL56F27

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FLIGHT TESTS OF FIFTEEN T-231 GUN-LAUNCHED ROCKET PROJECTILES

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SUMMARY

Flight tests of fifteen T-231 70-mm HEAA rocket projectiles (flight components of the T-263 HEAA rounds) were made at the Langley Pilotless Aircraft Research Station at Wallops Island, Va., to obtain flight trajectories at high quadrant elevation launchings and to obtain drag data.

Although all rounds were of the same general type, there were differences in nozzle cant angles, number of nozzles per round, shape of head and fuse, motor case length, and type of propellant. All projectiles were launched at an elevation angle of 60°.

Two of the projectiles tumbled; the remaining thirteen flew successfully. Maximum velocities varied between 2,775 and 3,185 feet per second. The time to reach maximum velocity varied between 1.3 and 1.95 seconds. Altitude measured 10 seconds after launching varied between 13,950 and 14,915 feet, and maximum altitude varied between 19,500 and 21,000 feet. Drag coefficients were obtained over a range of Mach number from 0.7 to 2.6. Maximum drag coefficients varied between 0.45 and 0.50. Results obtained from the last five rounds which were identical within manufacturing tolerances were in close agreement.

INTRODUCTION

For a number of years the Armour Research Foundation of Illinois Institute of Technology has been conducting a research program aimed at developing gun-launched rocket projectiles for use in a high cyclic rate of fire, short-to-medium range antiaircraft weapon. This program has been conducted for the Ordnance Corps, Department of the Army, and has been under the supervision of Picatinny Arsenal, Dover, N. J. The rocket motor for these projectiles has been developed by the Thiokol Chemical Corp., Redstone Division, Huntsville, Ala., under the supervision of Redstone Arsenal.

Numerous static and low quadrant elevation firings of the T-212 70-mm HEAA rocket projectile (T-231 when the practice version is used), which is the flight component of the T-263 HEAA round, had been made and indicated that the program had progressed to the point where data from launchings at high quadrant elevations were required to check theoretical calculations and serve as basis for initial design of fire control systems. At the request of the Office of the Chief of Ordnance, Department of the Army, launchings of various modifications of the T-231 70-mm HEAA projectiles were made at the Langley Pilotless Aircraft Research Station at Wallops Island, Va. The first series of firings, rounds 1 to 10, were made with the cooperation of Armour Research Foundation and the final series, rounds 11 to 15, with the cooperation of Picatinny Arsenal.

SYMBOLS

C_D	drag coefficient, $\frac{\text{Drag}}{qS}$
S	cross-sectional area, sq ft
V	flight velocity, ft/sec
W	weight, lb
a	acceleration, ft/sec^2
g	acceleration due to gravity, ft/sec^2
q	dynamic pressure, $\frac{1}{2}\rho V^2$, lb/ft^2
θ	flight-path angle, deg
ρ	air density, slugs/ft^3

DESCRIPTION OF T-263 HEAA ROUNDS USED IN FLIGHT TESTS

The T-263 round shown in figure 1 is similar to fixed artillery ammunition. The round slides into position so that the bore of the cartridge case is in line with the bore of the launcher barrel. The cartridge case acts as the breech for the projectile and also as part of the barrel for the projectile to travel through as the round is fired. The launcher propelling charge is positioned around the igniter in the space as indicated by the arrow in figure 1(b). The gases produced by the launcher propelling charge upon ignition propel the projectile out the muzzle of the launcher barrel and simultaneously flow in the direction shown by the arrow in figure 1(b) into the rocket chamber of the projectile and ignite the rocket grain. The rocket grain continues to burn after the projectile leaves the launcher muzzle and boosts the velocity of the projectile from a muzzle velocity of approximately 1,100 feet per second to a peak velocity of about 3,000 feet per second approximately 1.5 seconds after firing the round.

The rocket-boosted projectile of the T-263 round is designated T-231 and consists of three parts or subassemblies, namely the head, rocket motor, and nozzle plate. The external configuration of a T-231 projectile is shown in figure 2. Two types of heads were used, one with a 6.5-caliber ogive head and the other with a 12.5-caliber ogive head. Nozzle plates used differed as to number of nozzles, either 3 or 4, and nozzle cant angle, either 10° or 11°. The propellant was cast into the rocket case and the grain and case were thus handled as one part. There were some differences in the rocket cases, chiefly in length and weight. The grains were cast from several different batches of type T13E1 or TRX 132 propellant, both being of polysulfide-perchlorate composition manufactured by Thiokol Chemical Corp. The chief difference between T13E1 and TRX 132 is that TRX 132 contains approximately 1 percent MgO whereas T13E1 contains none. Table I indicates the type of nozzle plate, type of propellant, approximate propellant weight, and approximate projectile weight before firing and after burnout for each projectile.

TEST TECHNIQUES

Prior to firing, all rounds were temperature conditioned at approximately 70° F for a period of at least 12 hours. Launching angle was approximately 60°. The hand-operated launcher used for the firings is shown in figure 3, which also shows the SCR-584 and CW Doppler radar sets used for the tests.

Tracking the rockets with an SCR-584 radar unit provided azimuth, elevation, and slant range, as functions of time which could be used to compute altitude and azimuth as functions of horizontal range. A CW Doppler radar unit was used to obtain velocity time histories. Rawinsonde balloons were released at the approximate time of firing of the rounds to obtain air density and temperature and wind velocity as functions of altitude.

RESULTS AND DISCUSSION

Data analysis showed that there is close agreement in data obtained in the second series of firings, rounds 11 to 15, whereas, there is relatively poor agreement in data obtained from the first series of firings, rounds 1 to 10. This can be seen in slant range as a function of time (fig. 4), altitude as a function of horizontal range (fig. 5), and velocity corrected for wind as a function of time (fig. 6). Data obtained for round 1 are not presented in figure 4 because they were not considered to be of value ballistically. In a few other instances, certain data are not presented because radar data obtained were not sufficient.

Slant range at 10 seconds after firing (fig. 4) varied from 16,400 to 18,350 feet. Altitude measured 10 seconds after launching ranged from 13,950 to 14,915 feet, whereas maximum altitude varied from 19,500 to 21,000 feet, as shown in figure 5.

Maximum velocity achieved ranged from 2,775 to 3,185 feet per second, as indicated in figure 6, whereas the time to reach maximum velocity varied between 1.3 and 1.95 seconds. Some of the velocity-time curves show an increase in velocity several seconds after the rockets had reached peak velocity. This was caused by the reignition of slivers of grain that remained in the rocket combustion chambers after the majority of each grain had burned out. Variation in times to reach maximum velocity of several tenths of a second was caused mainly by differences in ignition characteristics of the rocket grains and also to some extent by differences in burning times of the rockets. Maximum variation of maximum velocity for rounds 11 to 15 was 1.3 percent.

In addition to data from SCR-584 radar and CW Doppler radar sets which were presented in figures 4, 5, and 6, rawinsonde data were necessary for the computation of drag coefficient. Air density and speed of sound as functions of altitude, obtained from rawinsond data, are presented in figure 7. It was assumed that the burnt-out weight of the round, which was used for computation of drag coefficient, was equal to the loaded weight of each round minus the weight of the combustible materials. Drag coefficient C_D was obtained by substitution in the following equation:

$$C_D = \frac{-W}{qS}\left(\frac{a}{g} + \sin\theta\right)$$

Drag coefficient as a function of Mach number (fig. 8) also shows good agreement for the second series of firings (fig. 8(c)) and relatively poor agreement for the first series of firings (figs. 8(a) and 8(b)).

Over a Mach number range of 0.7 to 2.6, maximum drag coefficients varied between 0.45 and 0.50 or 11 percent. Maximum variation of maximum C_D for rounds 11 to 15 was 1.6 percent.

Comparison of figure 5(a) with other altitude—horizontal-range plots indicates that round 1 fell far short of reaching the altitude and horizontal range of comparable rounds. Comparable data were not obtained for round 5. Comparison of figure 6(a) with other velocity-time plots indicates that round 1 had a sharp decrease in velocity after about 2 seconds and round 5 had a sharp decrease in velocity at about 0.75 second, which was before the rocket grain had burned out. When the magnetic tape that has recorded the CW Doppler signal reflected from a model in normal flight is run through the proper electronic equipment an audible signal is produced which gradually changes in amplitude and frequency. When this was done with the magnetic tapes for rounds 1 and 5 there was a rapid cyclic change in the amplitude of the recorded signals that sounded like a "warble," which indicated that the reflecting area presented by these rounds was rapidly changing in a cyclic manner as would be the case if the rounds were tumbling. It was thus concluded that rounds 1 and 5 tumbled. Both of these rounds had 6.5-caliber ogive heads. None of the rounds with 12.5-caliber ogive heads tumbled.

The fact that all the rounds with 6.5-caliber ogive heads were the same within the accuracy of manufacturing tolerances and that two out of six of these rounds tumbled indicated that these rounds were at best marginally stable and in two instances unstable.

An insufficient number of rounds were fired to determine the possible effects of the use of the different types of propellant and nozzle plates on the performance of the rounds.

CONCLUSIONS

Flight tests of fifteen T-231 70-mm HEAA rocket projectiles were made at the Langley Pilotless Aircraft Research Station at Wallops Island, Va. The following conclusions were made:

1. Of the rounds fired the reproducibility of performance was good for the five rounds 11 through 15, and was relatively poor for all other rounds fired.

2. Maximum velocity varied between 2,775 and 3,185 feet per second; the time to reach maximum velocity varied between 1.3 and 1.95 seconds.

3. Altitude measured 10 seconds after launching varied from 13,950 to 14,915 feet; maximum altitude varied from 19,500 to 21,000 feet.

4. Over a Mach range of 0.7 to 2.6, maximum drag coefficients varied between 0.45 and 0.50.

5. For rounds 11 to 15 the ~~maximum~~ variation of maximum velocity was 1.3 percent and the maximum variation of maximum C_D was 1.6 percent.

6. The rounds with the 6.5-caliber ogive head were marginally stable or unstable.

7. From the number of rounds fired, the effect of using the different propellants and nozzle plates could not be determined.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 13, 1956.

Wade E. Lanford

Wade E. Lanford
Aeronautical Research Scientist

Approved: Joseph A. Shortal

Joseph A. Shortal
Chief of Pilotless Aircraft Research Division

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TABLE I

SUMMARY OF ROUND CHARACTERISTICS AND TEST DATA

Round	Type number of round (a)	Caliber ogive head	Type propellant	Type nozzle plate (b)	Maximum velocity, ft/sec	Time to reach maximum velocity, sec	Maximum altitude, ft	Altitude at 10 sec, ft	$C_{D,max}$	Total assembled weight, lb	Burnt-out weight, lb	Propellant weight, lb
1	I	6.5	T13E1	4-10	3035	1.5	6,300	(c)	(c)	8.8	5.5	3.3
2	I	6.5	T13E1	4-10	3102	1.5	19,500	14,142	(c)	8.7	5.5	3.2
3	I	6.5	T13E1	4-10	3180	1.5	19,800	14,913	0.505	8.7	5.5	3.2
4	I	6.5	T13E1	4-10	3111	1.5	19,600	14,177	.487	8.8	5.5	3.3
5	I	6.5	TRX132	4-10	[d]2165	.75	(c)	(c)	(c)	8.8	5.5	3.3
6	I	6.5	TRX132	4-10	3176	1.5	20,950	14,840	.484	8.8	5.5	3.3
7	II	12.5	T13E1	4-11	2918	1.5	21,000	14,113	.459	8.6	5.7	2.9
8	II	12.5	T13E1	3-11	3093	1.9	20,300	14,263	.486	8.6	5.7	2.8
9	II	12.5	T13E1	3-11	3061	1.3	20,200	14,532	.489	8.6	5.7	2.8
10	II	12.5	TRX132	4-11	[d]3065	1.3	(c)	(c)	(c)	8.7	5.3	3.0
11	III	12.5	TRX132	3-11	2796	1.4	(c)	14,015	.498	9.1	6.3	2.9
12	III	12.5	TRX132	3-11	2782	1.4	20,090	14,002	.491	9.1	6.3	2.9
13	III	12.5	TRX132	3-11	2788	1.4	20,250	14,145	.490	9.2	6.3	2.9
14	III	12.5	TRX132	3-11	2819	1.4	20,250	14,124	(c)	9.1	6.2	2.9
15	III	12.5	TRX132	3-11	2792	1.4	(c)	13,983	(c)	9.2	6.3	2.9

[a]Type number of round specifies that round had dimensions as of corresponding type number as listed in table of figure 2(a).

[b]In column headed by type nozzle the first number, 3 or 4, indicates the number of nozzles that the nozzle plate had, and the second number, 10 or 11, indicates the nozzle cant angle in degrees.

[c]Indicates data not obtained.

[d]Not corrected for wind.

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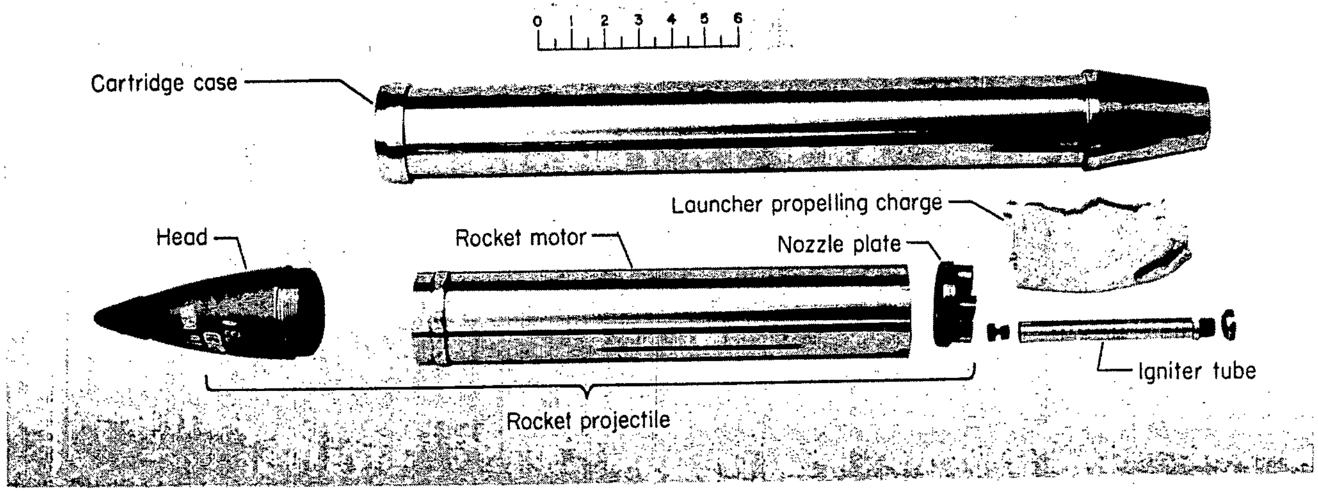
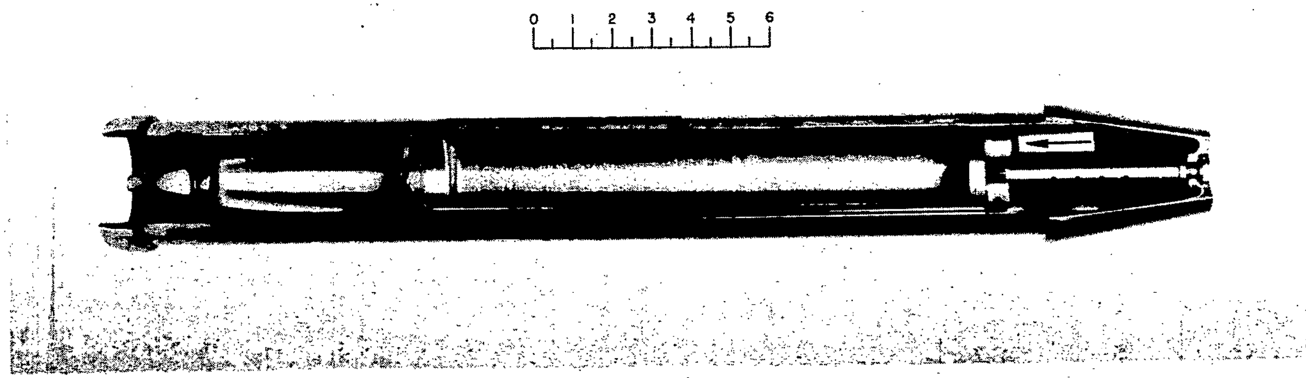


(a) Unassembled parts.



(b) Cutaway.

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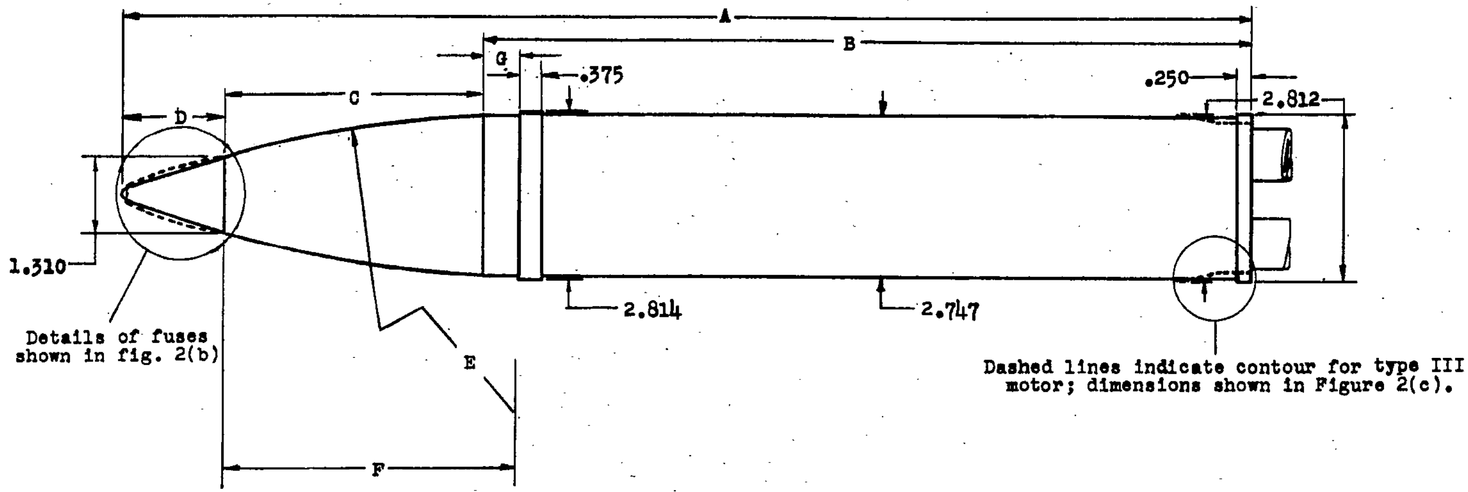
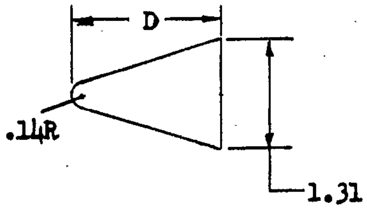
Figure 1.- Photographs of the T-263 round.



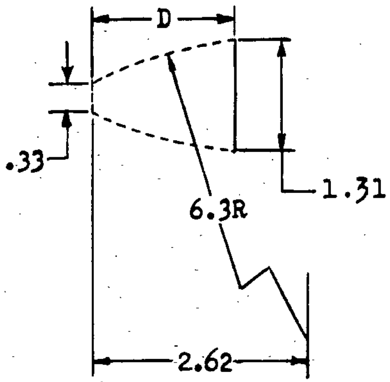
Type Round	Dimension						
	A	B	C	D	E	F	G
I	19.761	13.342	4.552	1.844	17.844	5.097	.632
II	19.799	12.503	4.835	2.430	34.375	7.489	.890
III	18.880	12.300	4.840	1.740	34.500	7.489	.787

(a) Complete rounds.

Figure 2.- External configurations of the three types of T-231 projectiles fired. All dimensions are in inches.



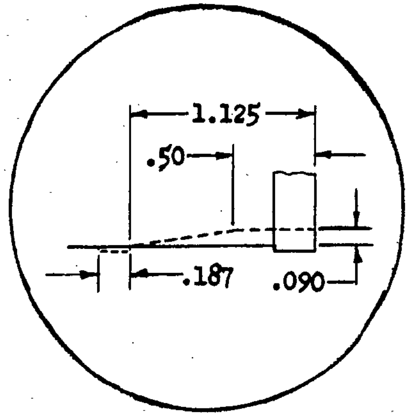
Rocket types I and II



Rocket type III

Rocket Type	Dimension D
I	1.844
II	2.430
III	1.740

(b) Three types of fuses.



(c) Details of rear of type III round.

Figure 2.- Concluded.

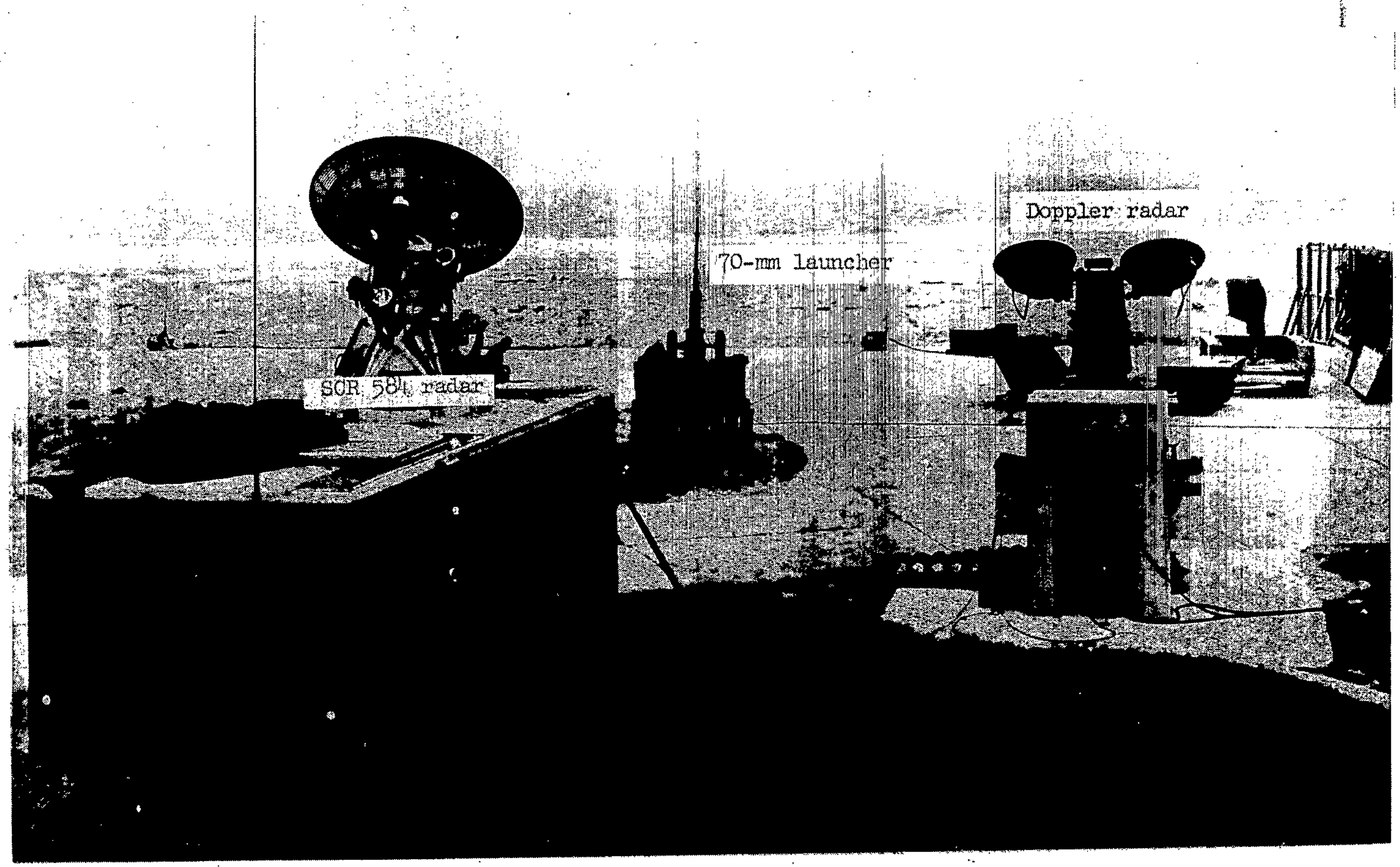


Figure 3.- Firing set up.

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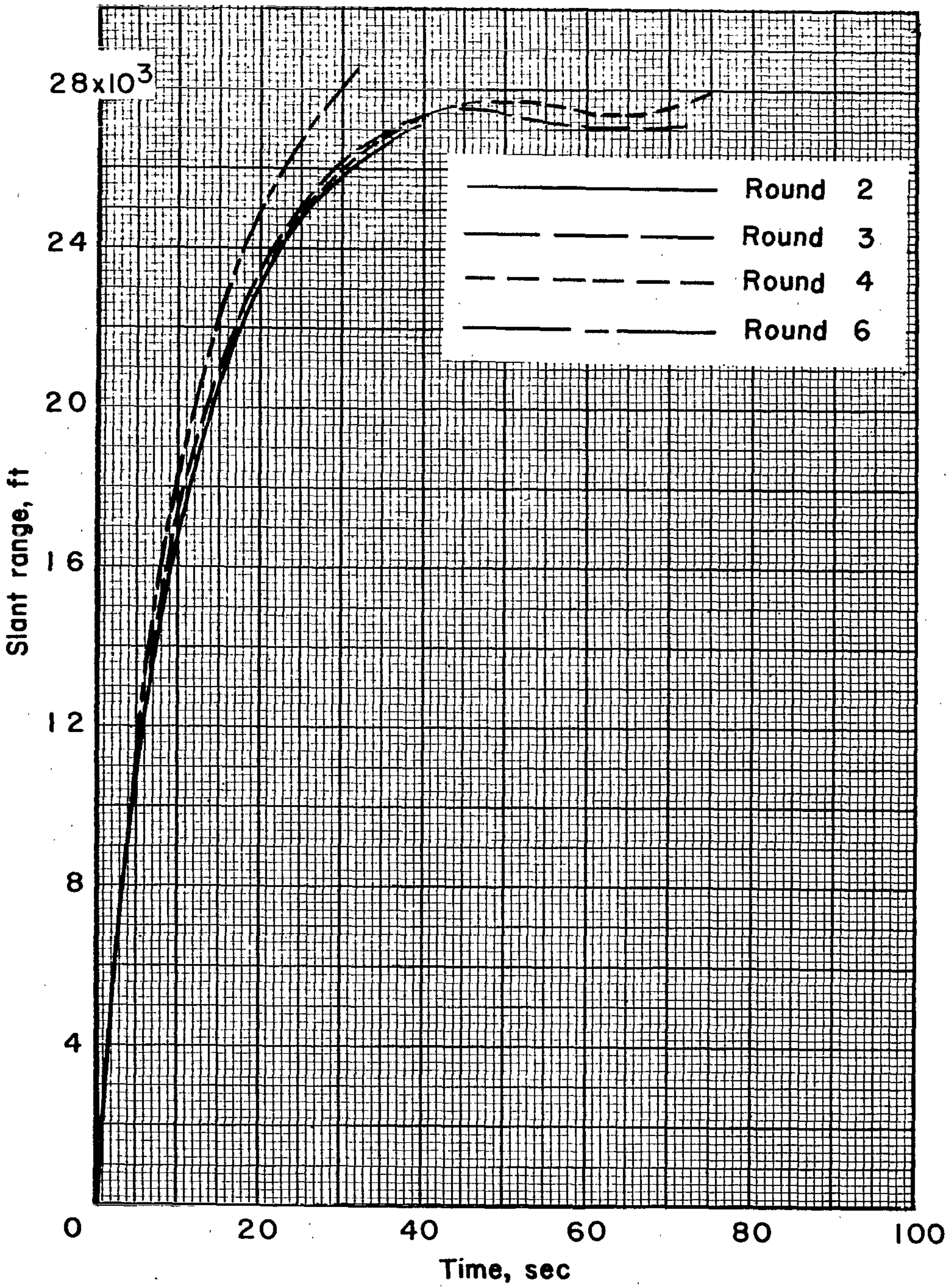
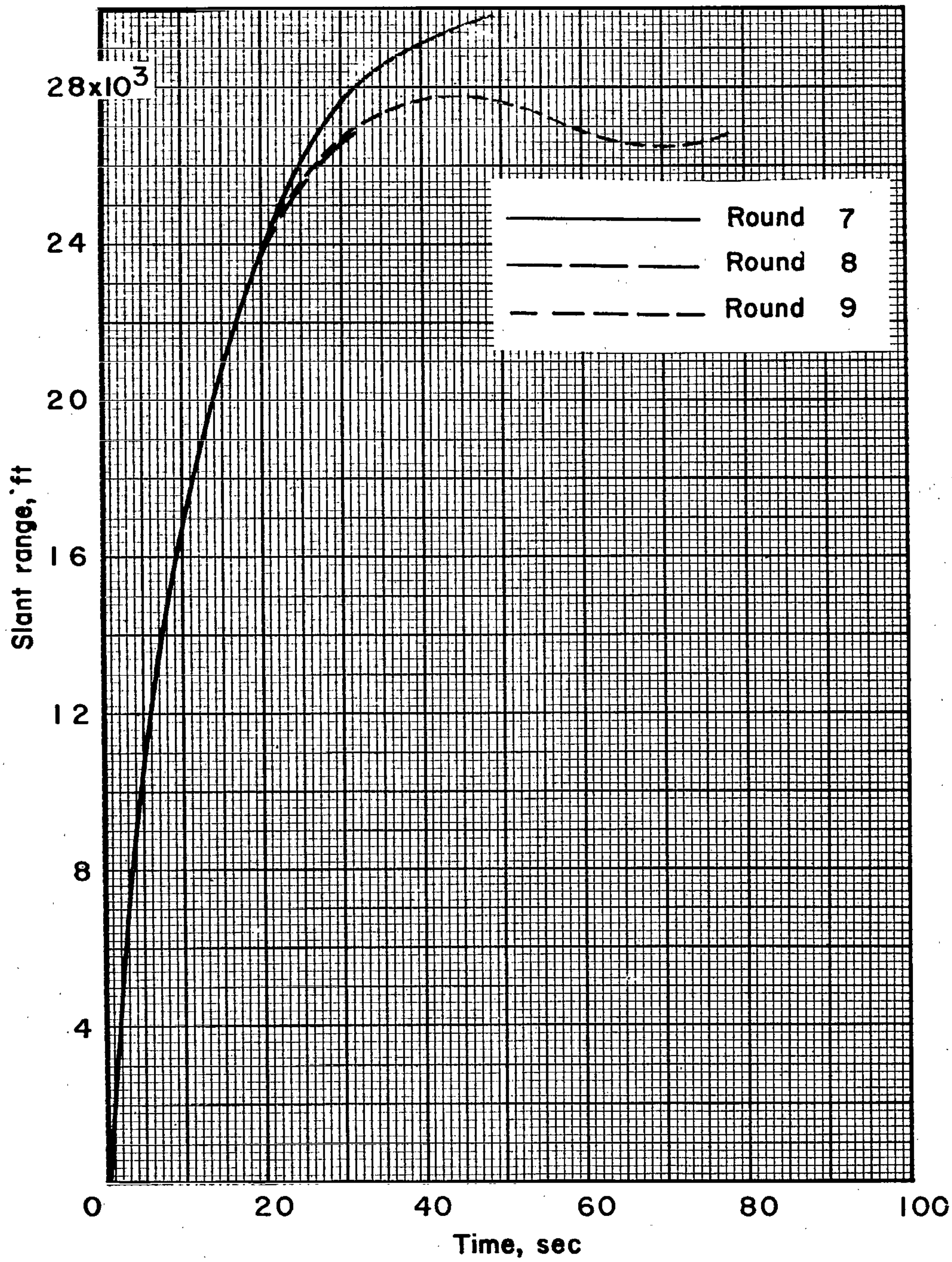


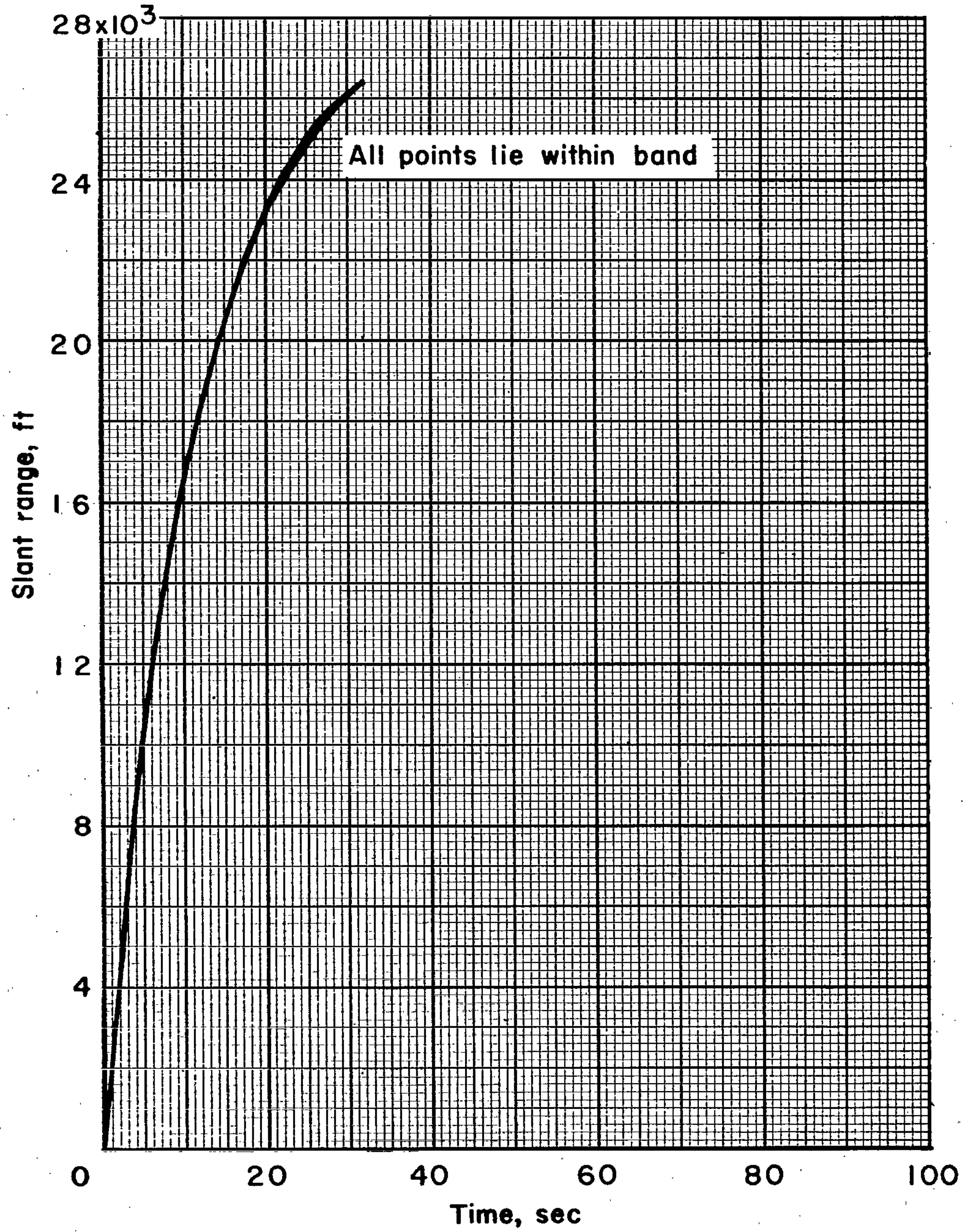
(a) Rounds 2, 3, 4, and 6.

Figure 4.- Slant range as a function of time.



(b) Rounds 7, 8, and 9.

Figure 4.- Continued.



(c) Rounds 11 to 15.

Figure 4.- Concluded.

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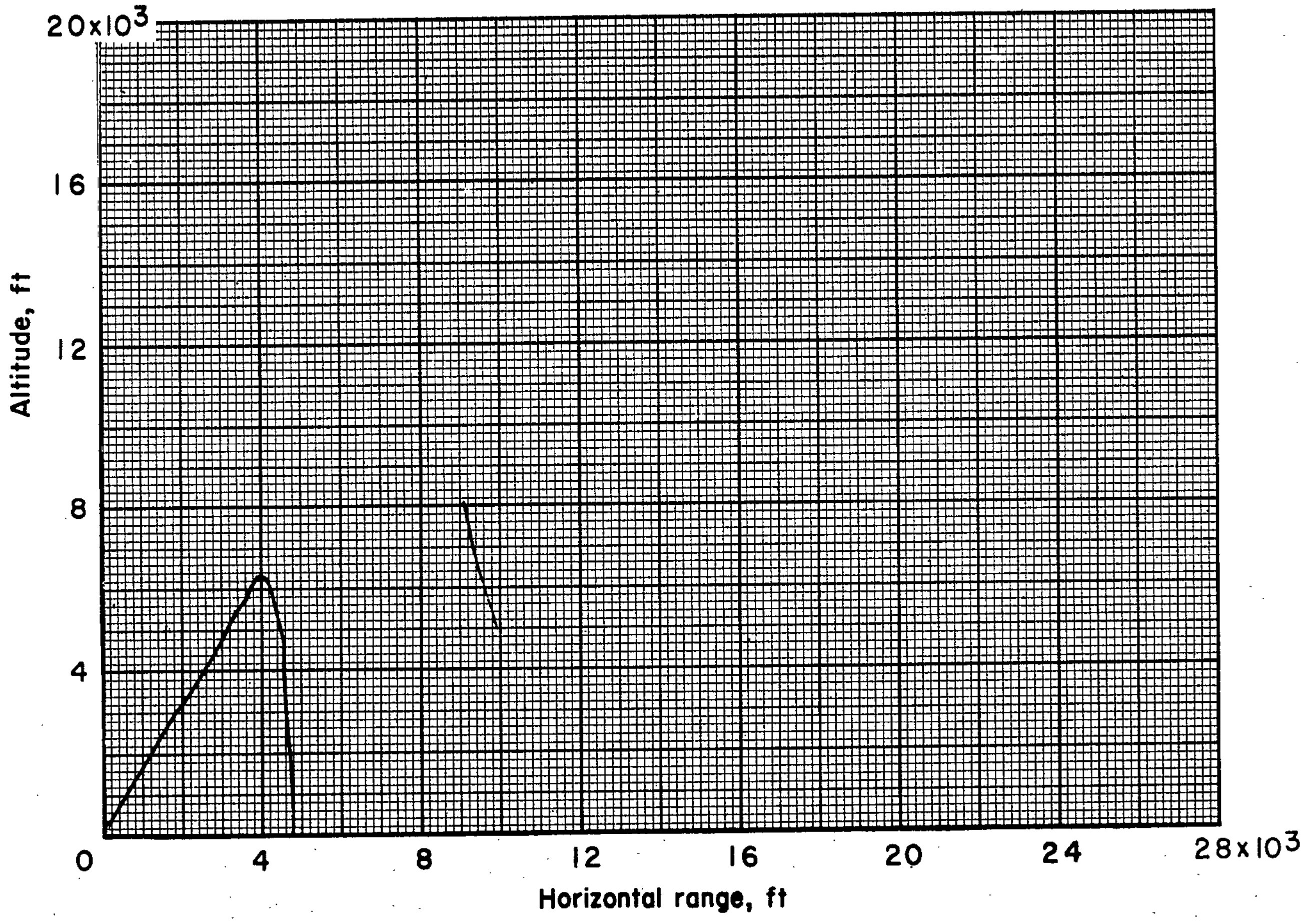

(a) Round 1.

Figure 5.- Altitude as a function of horizontal range.

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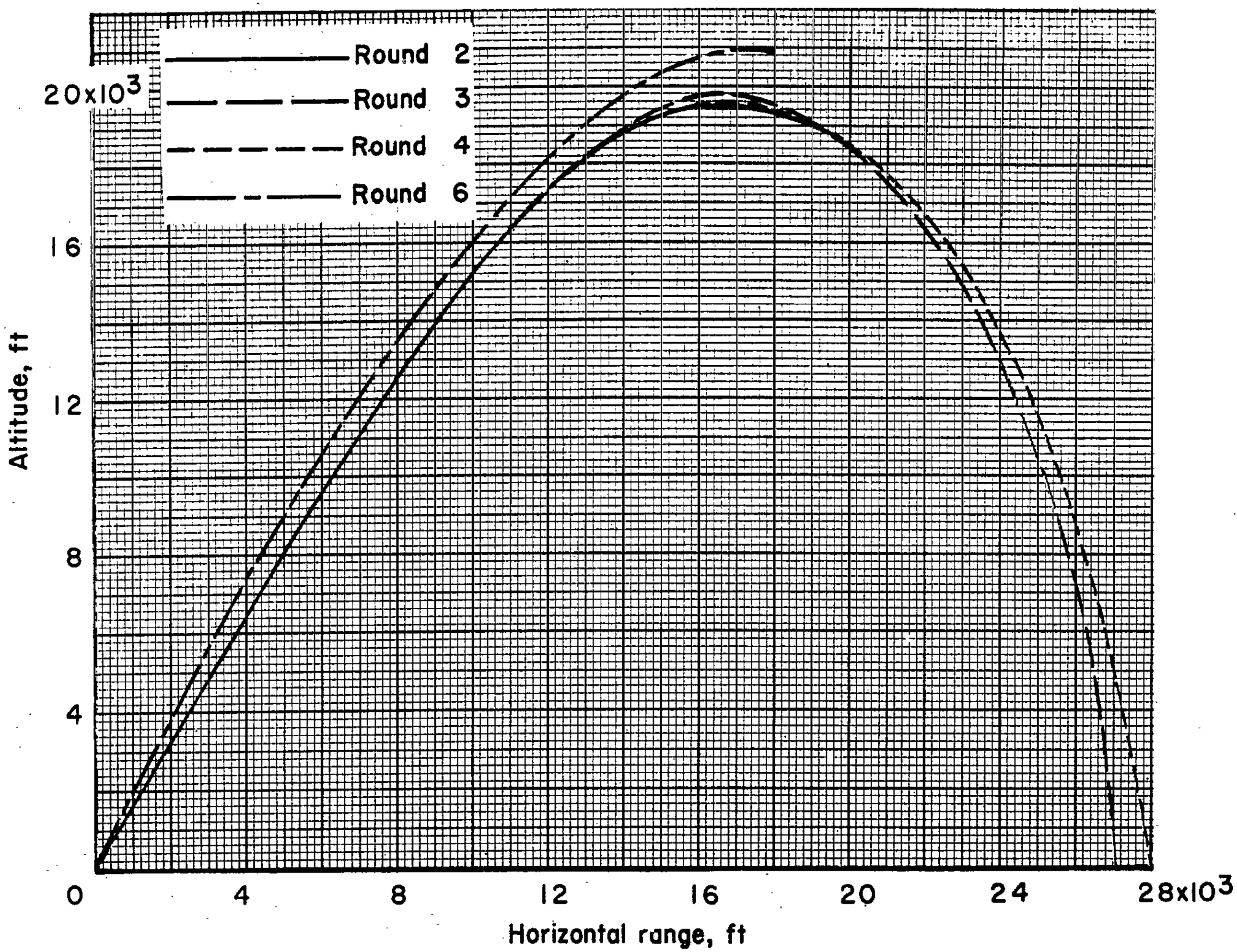

(b) Rounds 2, 3, 4, and 6.

Figure 5.- Continued.

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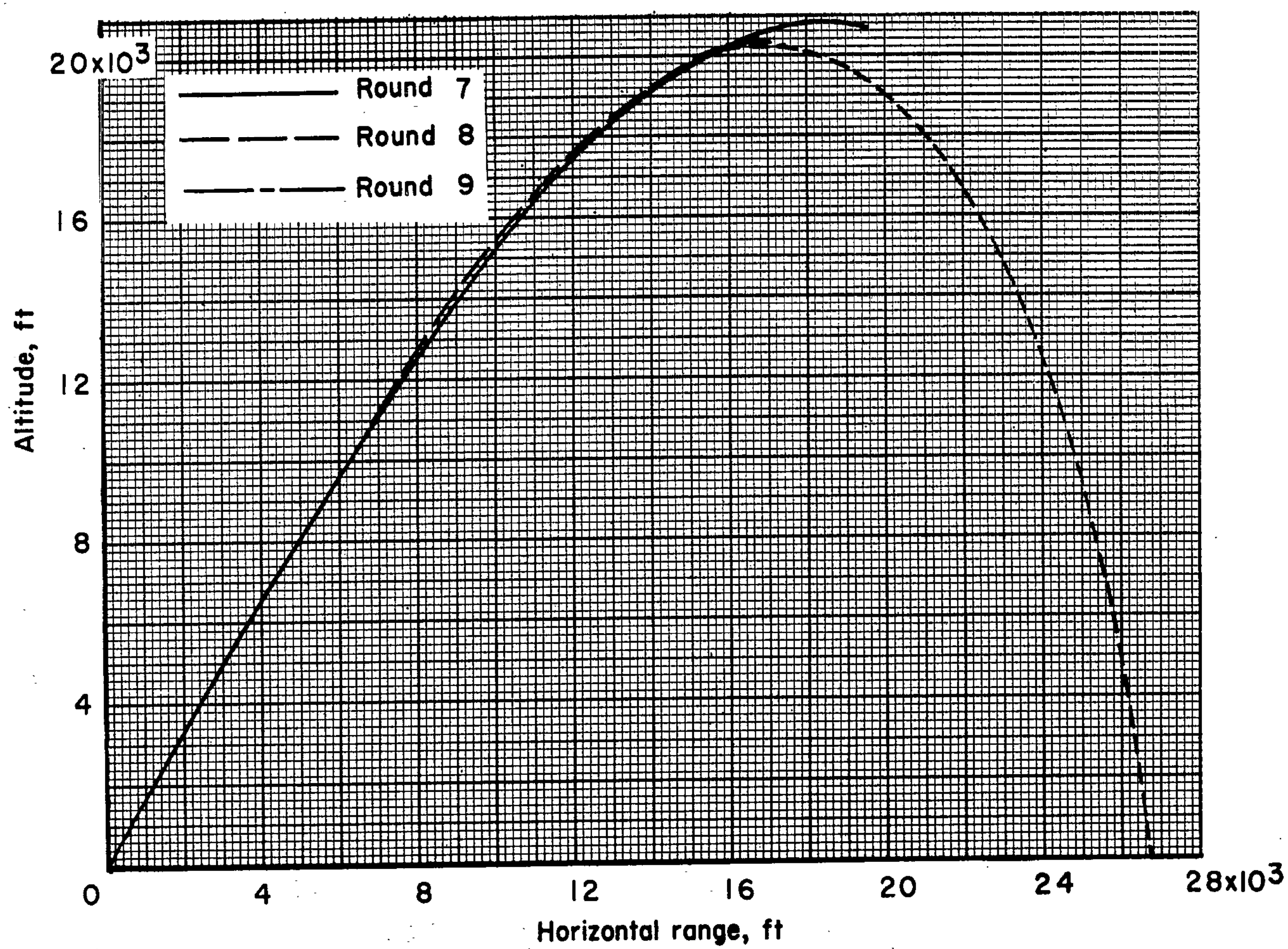
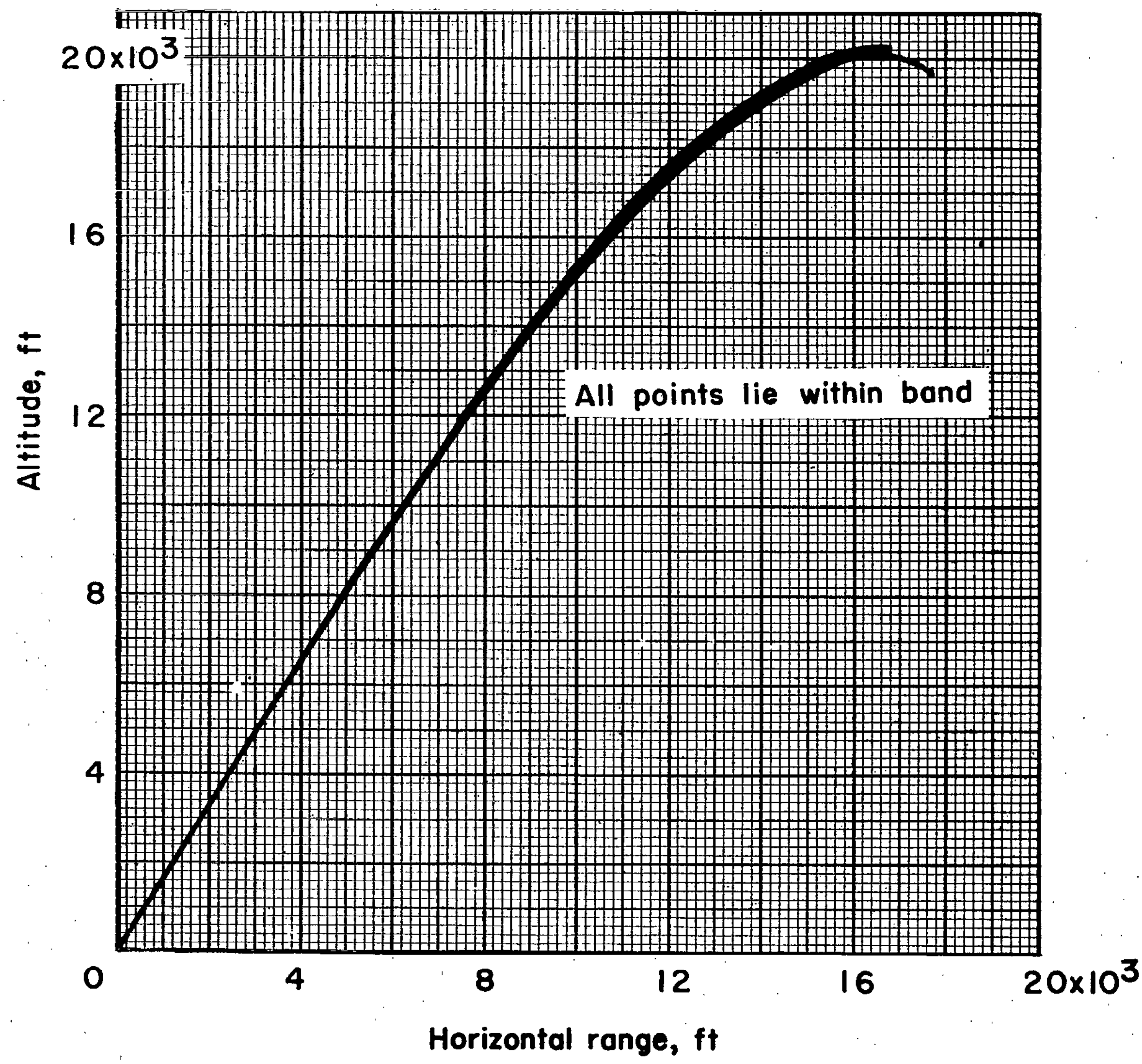


(c) Rounds 7, 8, and 9.

Figure 5.- Continued.



(d) Rounds 11 to 15.

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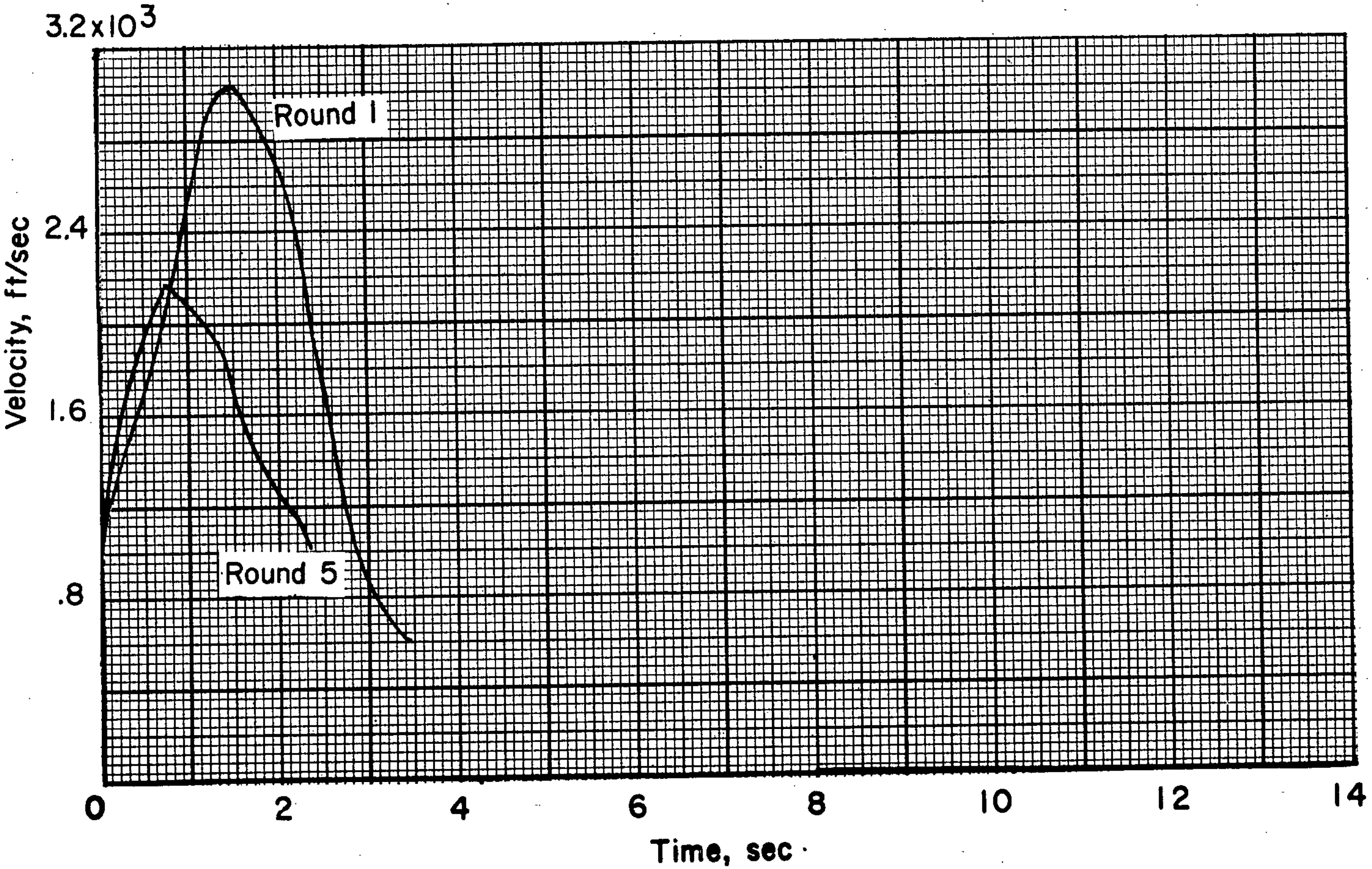
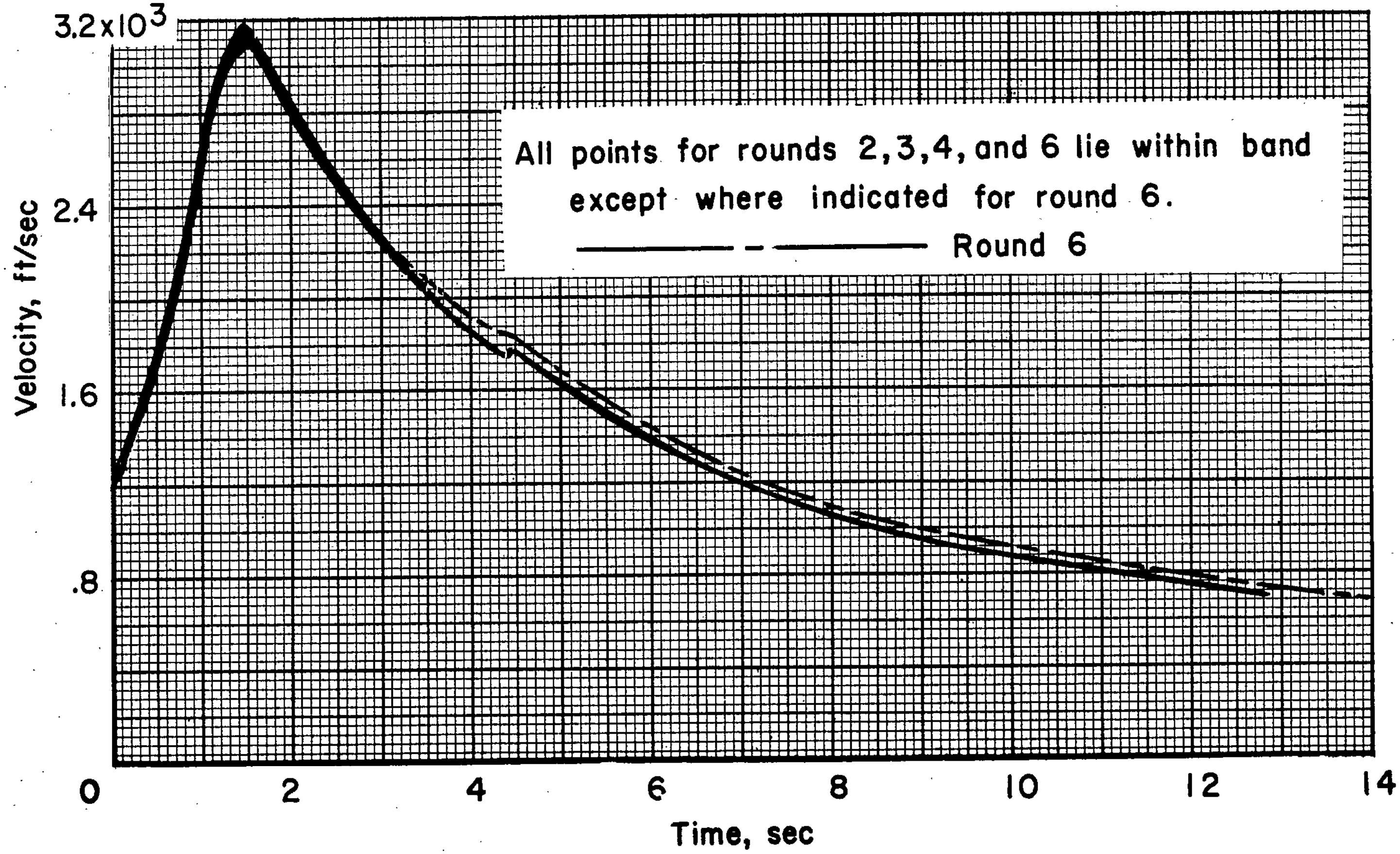


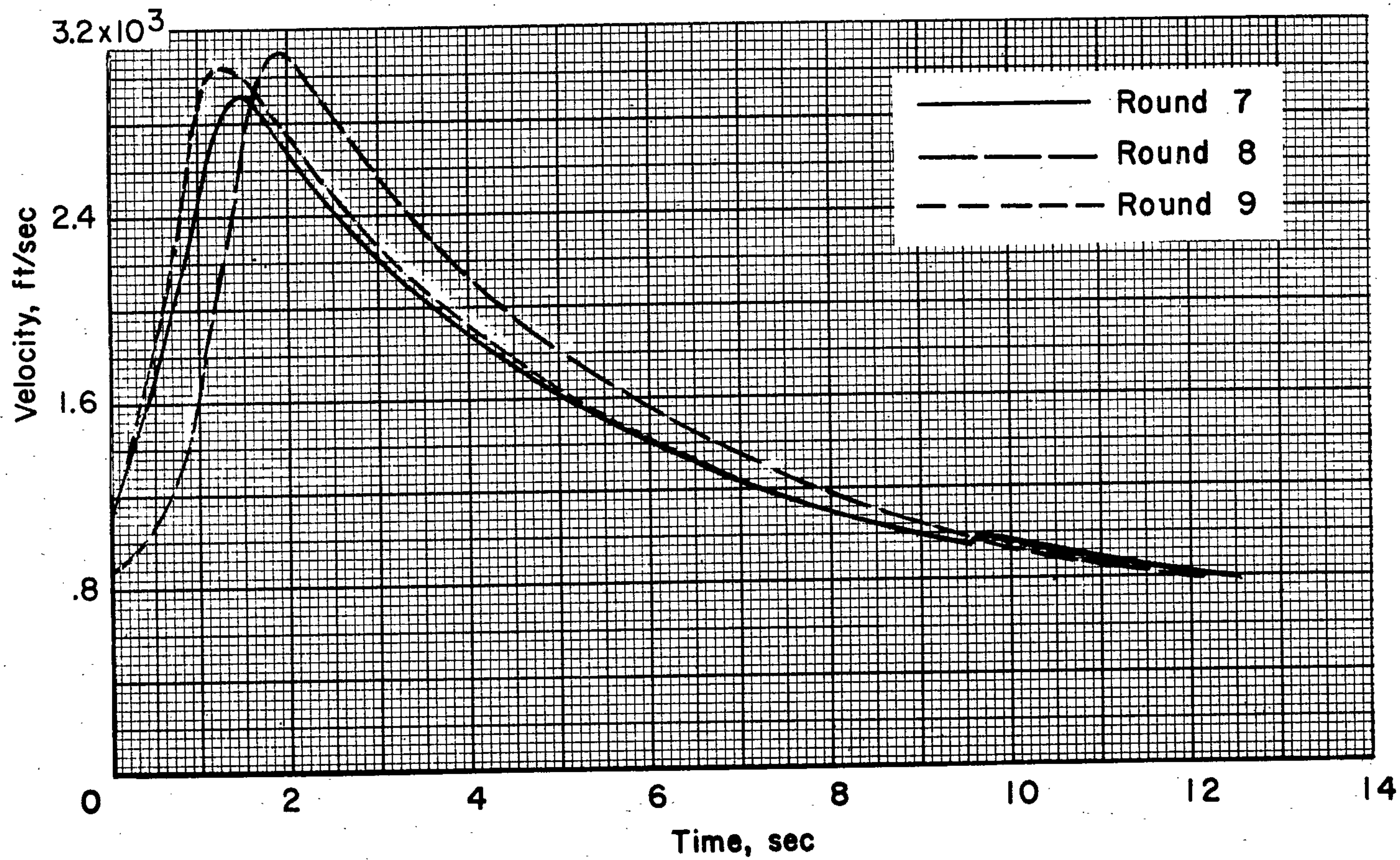
(a) Rounds 1 and 5.

Figure 6.- Velocity as a function of time.



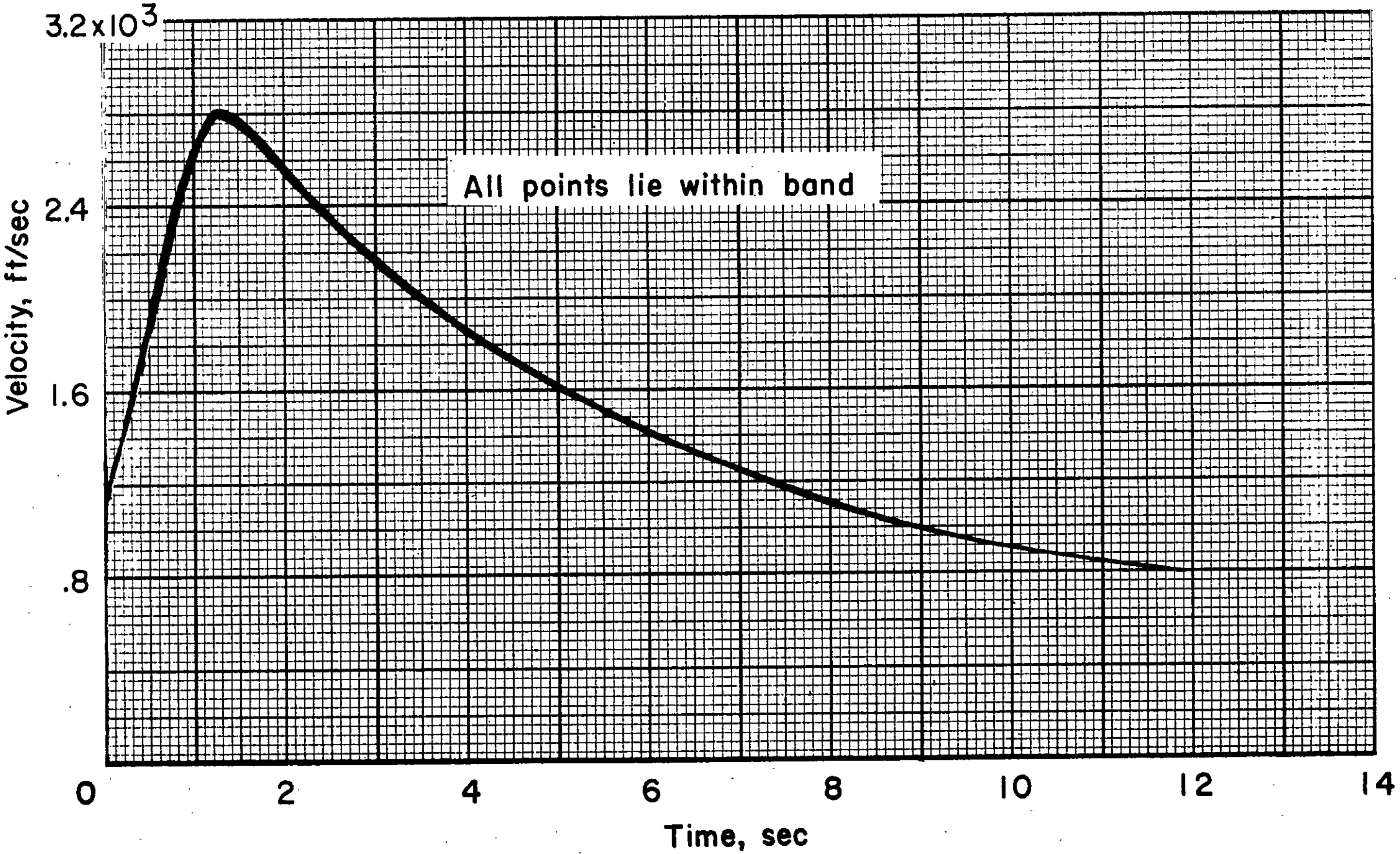
(b) Rounds 2, 3, 4, and 6.

Figure 6.- Continued.



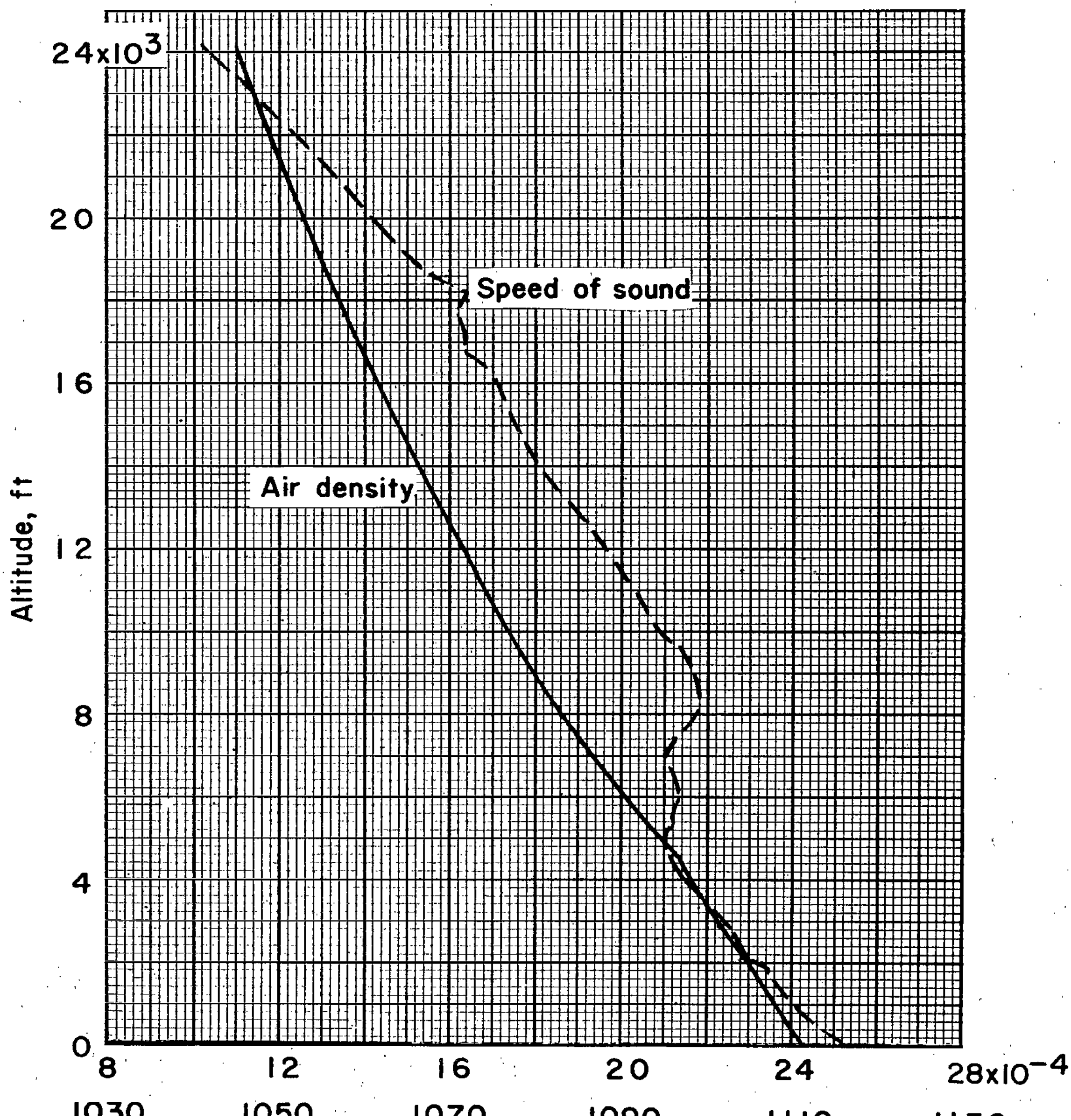
(c) Rounds 7, 8, and 9.

Figure 6.- Continued.



(d) Rounds 11 to 15.

Figure 6.- Concluded.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Speed of sound
Air density
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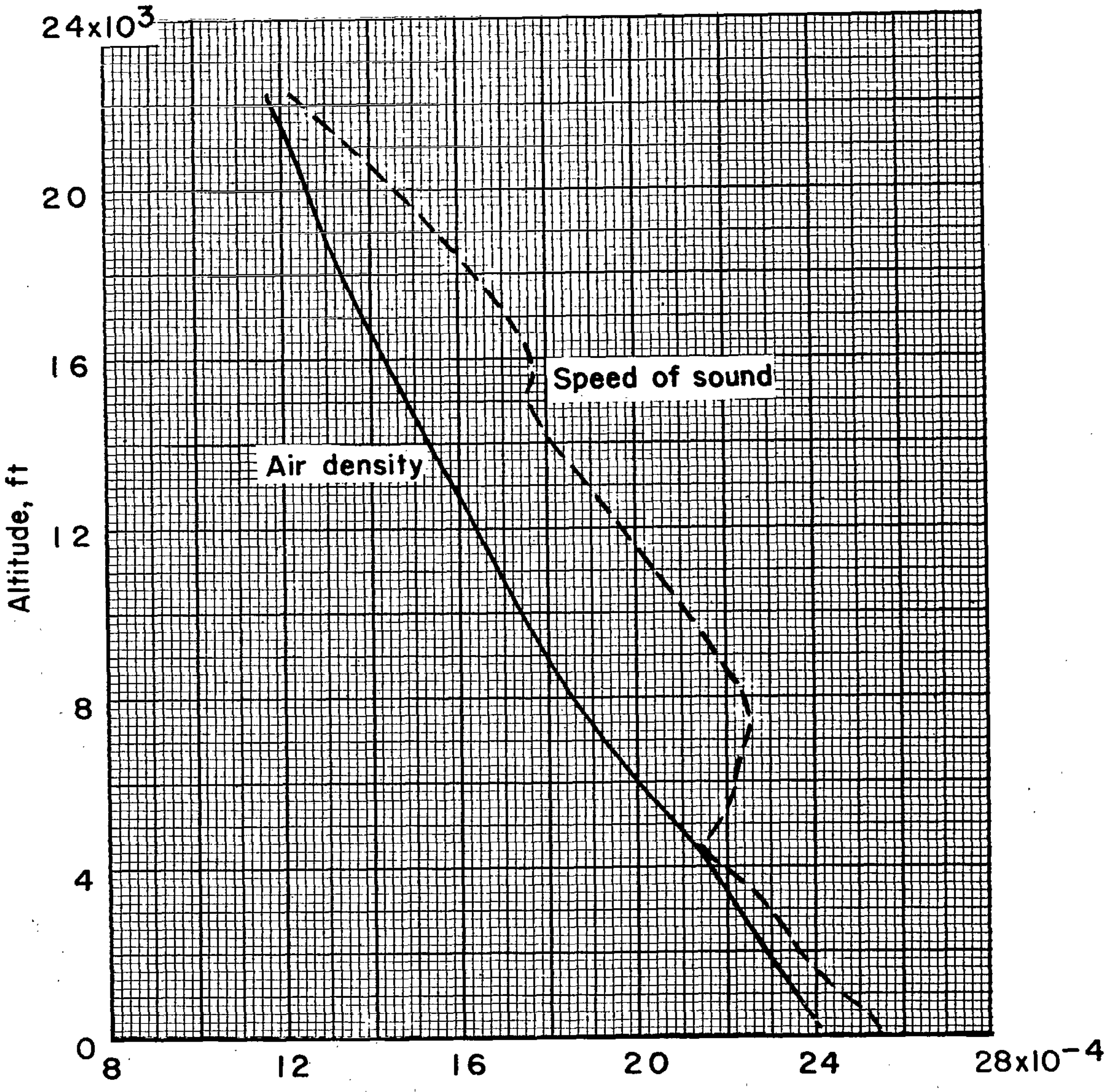
12
16
20
24
28x10^-4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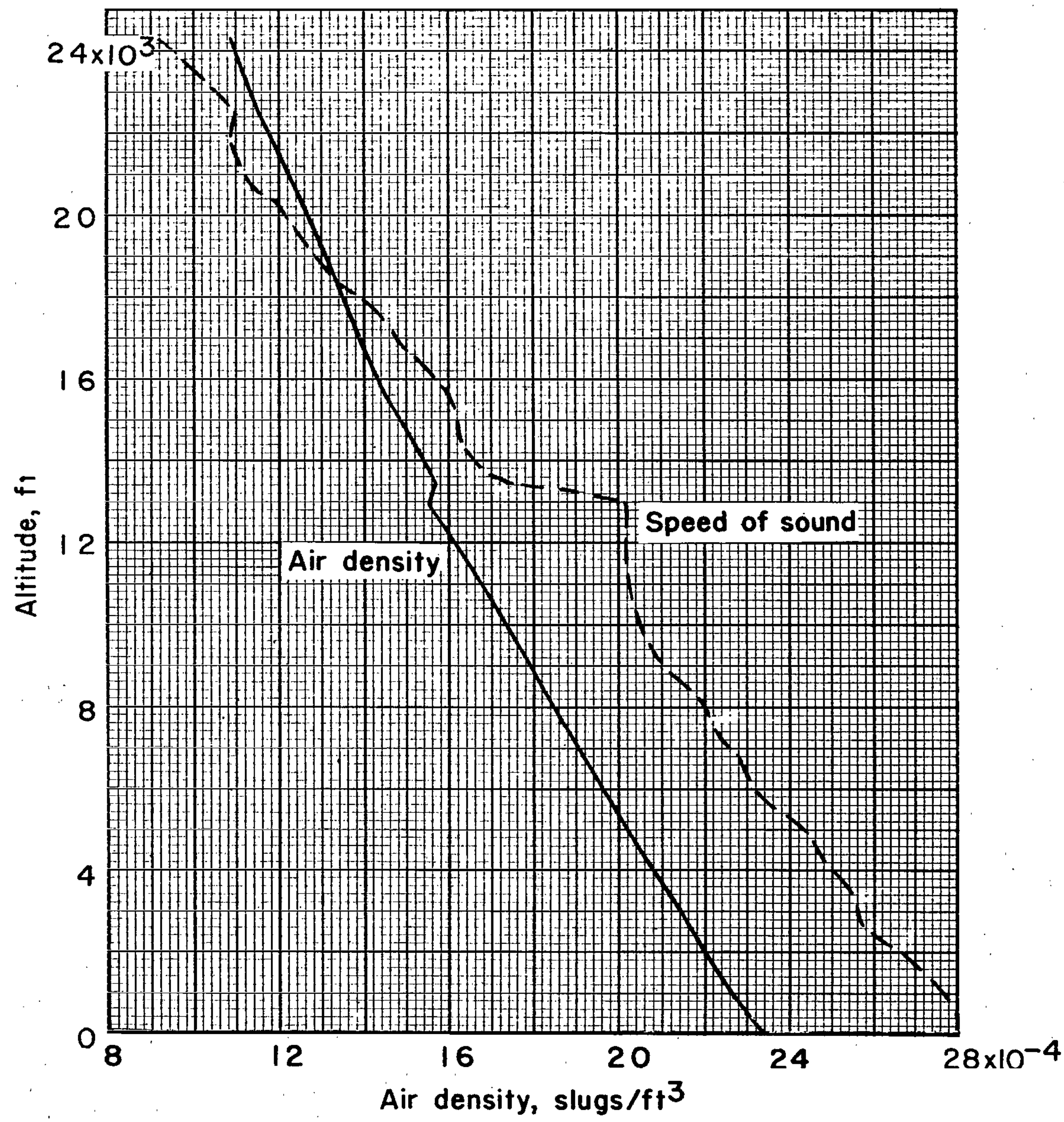
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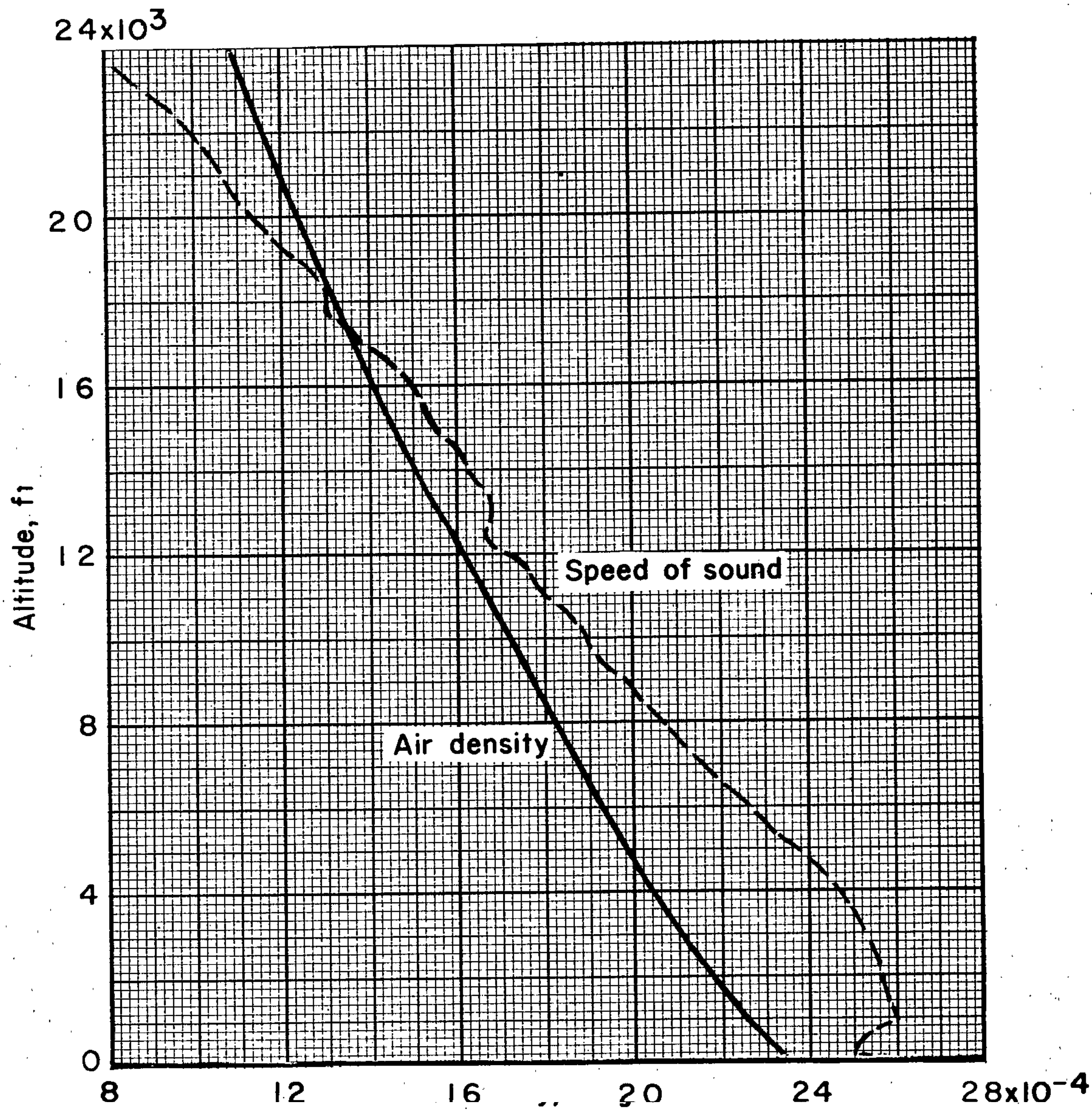
Air density
Speed of sound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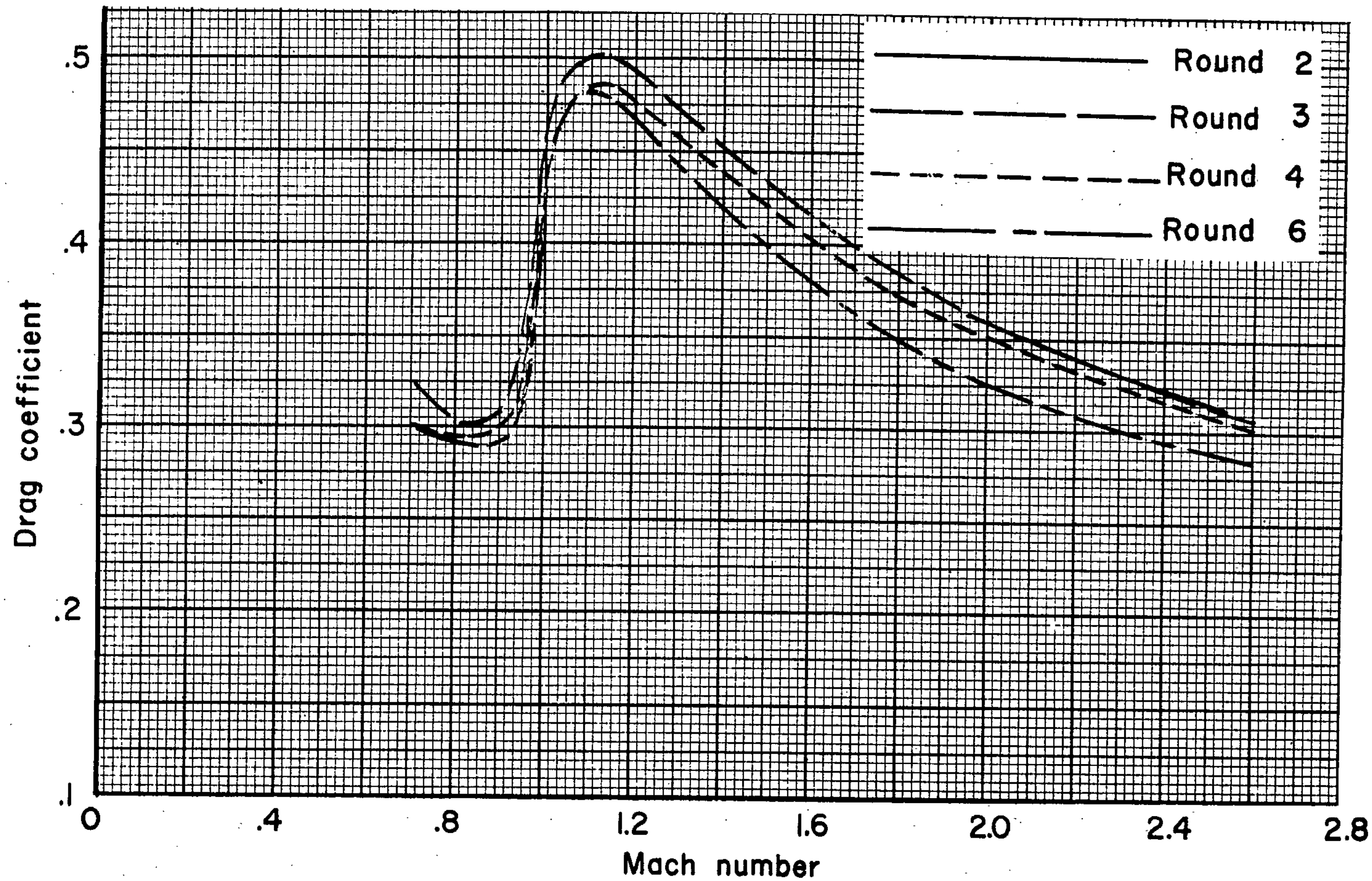

(a) Rounds 2, 3, 4, and 6.

Figure 8.- Drag coefficient as a function of Mach number.

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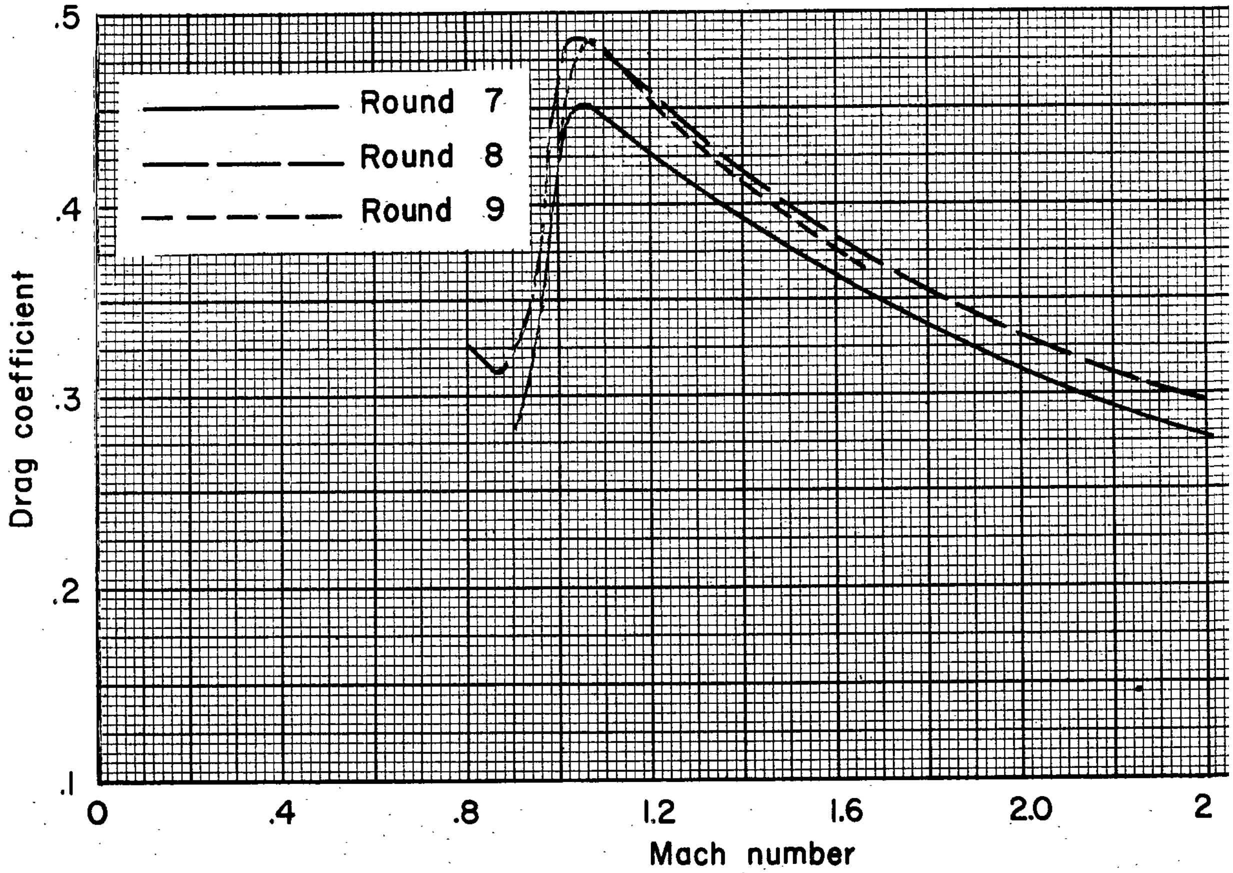
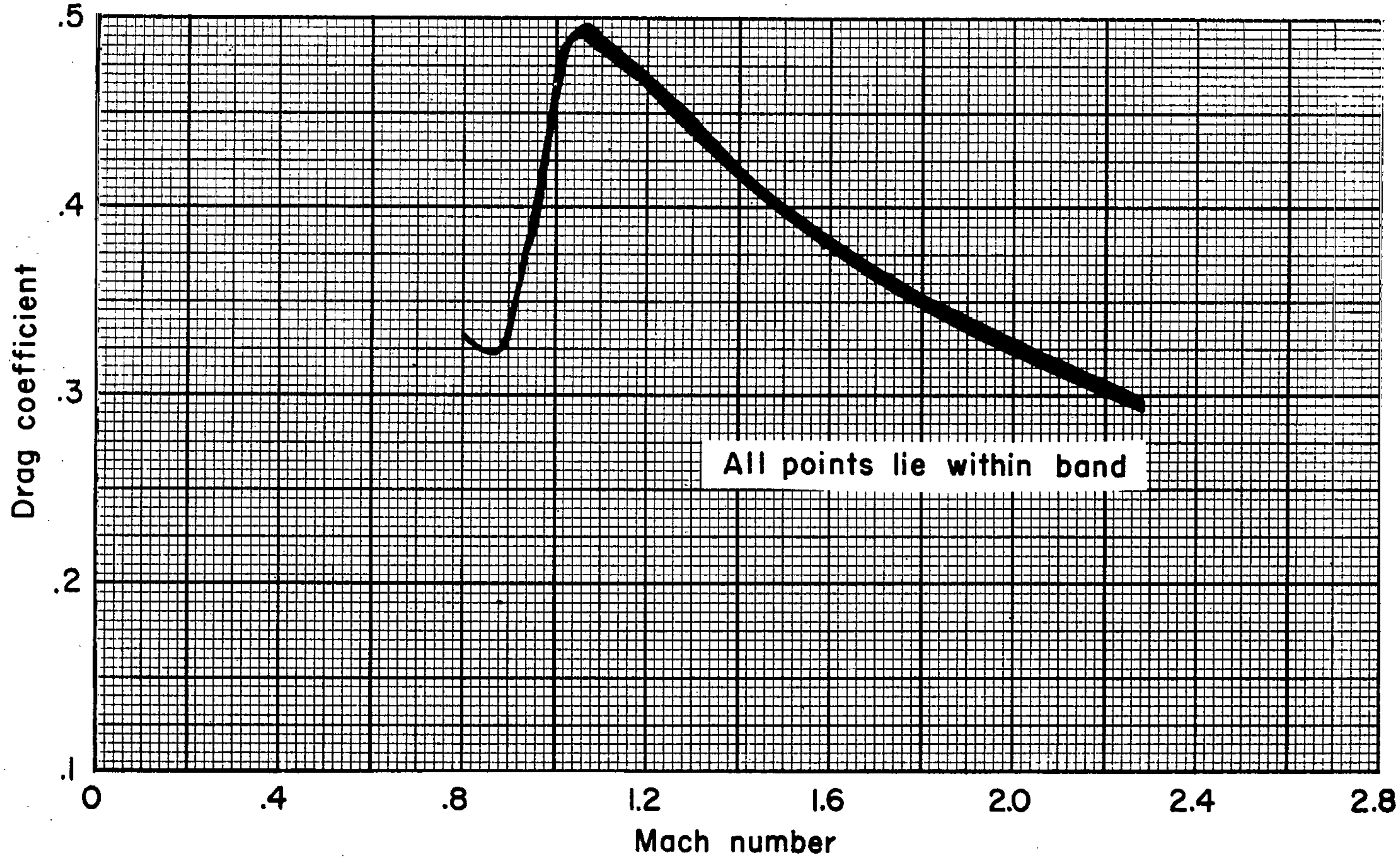


(b) Rounds 7, 8, and 9.

Figure 8.- Continued.



(c) Rounds 11 to 15.

Figure 8.- Concluded.

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ABSTRACT

Flight tests of fifteen T-231 70-mm HEAA rocket-boosted antiaircraft projectiles (flight components of the T-263 HEAA rounds) were conducted to obtain flight trajectories at high quadrant elevation launchings and to obtain drag data.